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THE EFFECT OF CONFINEMENT SHAPES UPON THE BLOWOFF LIMIT ON TANGENTIAL SWIRL BURNER

HAYDAR JANNA[1] & Dr. MOHAMMAD ABDULSADA[2]

[1]Master in Power Engineering, Department of Mechanical Engineering, College of Engineering University of Al-Qadisiyah, Al-Qadisiyah, Iraq

[2]Assistant Professor, Department of Mechanical Engineering, College of Engineering University of Al-Qadisiyah, Al-Qadisiyah, Iraq

ABSTRACT

In the nearest future, the fossil fuels will be the major source of energy. Growing consumption of environment- friendly energy renovation indicates that pollutants, like CO and NOx, should decrease. The burning of fossil fuels will produce more than two or three of world production of energy today and will continue over a century. This phenomenon attracts our attention in this paper, which aims to minimize the combustion process unsteadiness. It includes blow off phenomena and develops the shape of tangential swirl burner exhaust. Earlier studies have revealed that swirl number more than one of the swirl burner of swirl is categorized to generate high swirl flow, which is the finest amongst the other kinds of combustors. As a result, the design, make and utilize of this burner with a swirl number was one of the investigation goals that will be accomplished by the empirical part regardless many experimental hardships. The empirical structure of the study is to display the impact of adding conical confinements shape instead of cylindrical nozzle to the burner on blowoff limit through employing liquefied petroleum gas (LP gas)as an operating fuel and examination this for all combustion modes. As proved by the tests out comes, the addition of conical orifice confinements to the swirl burner has improved the incidence of blowoff boundaries in comparison with the cylindrical nozzle confinement for all modes of combustion and the mechanism of composition that will be elucidated in the following parts of this research.

KEYWORDS: Blowoff, Swirl, Burner & Confinement

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Original Article

INTRODUCTION

In spite of constant progress in the energy production field in several shapes in the world, the gas turbine and their production of energy are currently the prevailing, which contribute by more than 58% of producing energy in the world. Due to the vital location of the combustor between the compressor and turbine, the engineering designer should have sufficient background and adequate information about the source of energy engineering sciences focus on combustion related subjects to achieve the highest efficacy for combustion process with low consumed fuel and low emissions adding to that other consider proportion ns of designing gas turbines for the sake of steady performance without any operating problem as blow off when operate during different circumstances and demands.

Generally, the swirl flow of three dimensions flow, could be well-defined as an axial-tangential vortex movement. Therefore, the goal of swirling flow is to generate an accord speed area between the diverse speeds of the speed of the flame and the mixture[1, 2]. This low speed accord area that will activate reactants and re circulate heat can happen at it is called central recirculation zone (CRZ)[3, 4]. The generation, strength and size of this region rely on

the vortex breakdown. Through a simple principle, the vortex breakdown philosophy can be expressed through a sudden extension in exit swirl that leads to create in activity points downstream and these inactivity points lead to decrease of axial flow (so decrease in concord speed) and reduction of the pressure gradient in flow route could be the reason of an inverse flow. Other elements affect the creation of central recirculation region involve the burner form, equivalence proportion and swirl force[5, 6]. The swirl number denotes[7] an essential element in swirling flow while a the quantity without dimension refers to the proportion of axial flux of tangential momentum over multiply axial flux of axial momentum by the half of exit diameter of the outlet[8]. Due to difficulty and complication this unstable and complex flow in calculations for all components include in the calculation of swirl number, the geometrical swirl number (Sg) is employed in the calculation of the swirl number[9, 10]. The geometrical swirl number is a significant limitation and vital element in creating the swirl region and the extent of strength of the flow and the generation of the central recirculation zone (CRZ). Several papers[11, 12]denoted there is a creation of central recirculation region even at low layers of swirl numbers, but several studies[9]demonstrated the beginning of central recirculation region starts with swirl number equivalent or more than 0.6.

In the studies of Syred, Valera-Medina and Alsaegh, [3, 13-17] they demonstrated the decrease in combustor size and to accomplish the combustion steadiness (with a existence of high turbulent flame speed) containing flash back and blowoff limitation resulted from the swirling flow within the burner. Moreover, they achieved that by the processing vortex core (pvc), which lead to these structures because of haphazard vortices. The processing vortex core that develops blending process among reactants through maximizing the turbulence intensity and develops the flame steadiness but its helical form that decreases the recirculation of heat by stable and continuous frequency, and as a sequence increases the flame unsteadiness[18, 19]. It means PVC formation weakens creation of CRZ.

The phenomena of blowoff indicate split-up of flame from its steady location and then Extinguish. It is extremely lean blend[20]and this is the key element of blowoff occurrence. Many approaches might be utilized to raise flame resistance against the blowoff like using the bluff-bodies and swirl burners that will permit the blend of flammable mixture with hot gases so it maximize signition continuity and subsequently resistance to blowoff. The development of central recirculation region in swirl burner decreases the probability of the blowoff occurrence by expanded blowoff boundaries. Several papers[21-23]have revealed by Damköhler(Da) relation that the cause of blowoff phenomena is time of reactants in reaction region (t_u) is lower than the period needed to finish the chemical reaction (t_c).

$$Da = \frac{t_u}{t_c}$$

The period of reactants in the reaction region denotes the proportion of recirculation region length (d) to the axial exit burner speed (u_b) and required time to finish the chemical reaction refer to the proportion of the thermal diffusivity α) to the square laminar flame speed(s_l^2), so the Damköhler equation[24] becomes:-

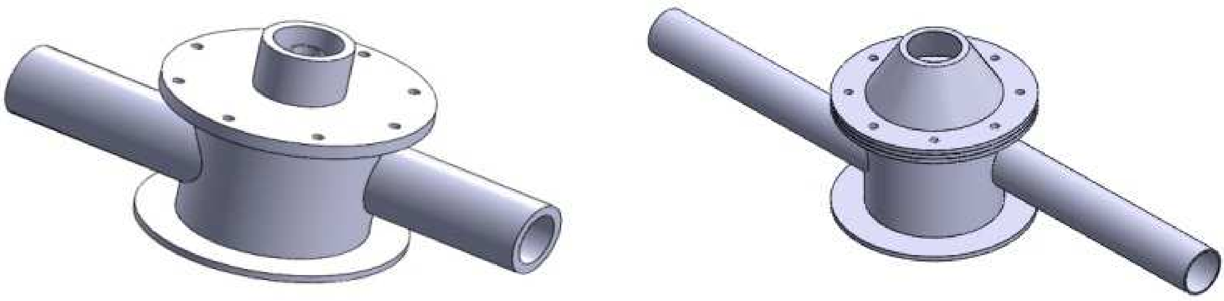
$$Da = \frac{d\, s_l^2}{\alpha\, u_b}$$

Due to temperature change in the burner, the axial speed also changes because of the change of Reynolds number. Moreover, the symbol (d) is a variable term that relies on the form of recirculation region. Therefore, it is difficult to calculate the Damköhler number. Many researches [25-28] examined the impact of using the bluff-bodies flames on the blowoff borders and they concluded that the extension of gas by the flame gives flame great resistance to the blowoff boundaries. Some studies [4, 11, 29]stated that the relationship between the blowoff and the equivalence proportion , as

denoted the blowoff occurs with very lean combination[28], that means the new alternate fuels particularly comprising higher percent of hydrogen[30-32], and has an equivalence proportion less than other forms of fuels, as a result, the burner could work with less temperature. Flammability limitations may lead vital element in the blowoff existence. Rashwan [33]in his empirical study of atmospheric partially premixed oxy combustion flames affixed on a pierced plate burner shows that the process with oxygen portion less than 29% isn't probable over the measured range of equivalence proportion. Extinction on upper flammability limitation happens by flashback when oxygen fraction surpasses 42% and at the less flammability limitation, extinction happens by blow-off when oxygen fraction decreases more than 29% but Hayakawa [34]concludes in his empirical study of stability and emission features of ammonia/air premixed flames in swirl combustor to lean and even rich blowoff boundaries are close to the flammability limitations of ammonia flames.

EXPERIMENTAL SETUP

Swirl combustor with two tangential inlets, which is employed for the empirical aspect of this piece of work is mapped out and made at Al-Qadisyah University /College of Engineering laboratory and stainless steel used in materials to resist extreme heat burnet fuel. The improved newly designed combustor has a flexibility of changing the injector with diverse radius. Combustor design in the way that give swirl number will equal 1.02, that is categorized as a high flow swirl the schematic diagram of the combustor present in figure 1:-



A B

Figure 1: Two Types of Confinement Shapes A-Cylindrical and B-Conical Mouth.

The burner may handle all methods of combustion including the premixed combustion through using double inlet ways of feeding mixture. The combustor shape and other supplements qualify it to handle all kinds of fuel, this combustor can use natural gas as the new designer scope to use the natural gas as a main fuel for the gas turbine combustor. The work accomplished in exceptional circumstance by additional conical nozzle that is made out of similar material of burner by using variables machinery techniques. The place of con nozzle is at the rear section of the combustor exit orifice with exterior radius equivalent to the combustor plenum radius and interior diameter equivalent to the combustor outlet orifices and length of half the combustor plenum length. Different flow meters types are used in study to specify the amount the of air and fuel mass by either measuring volumetric floe rate by use the turbine flow meter or traditional flow meter.

RESULTS AND DISCUSSIONS

In this paper, the tangential swirl burner is employed to indicate the flame steadiness boundaries at the standard atmospheric circumstances. This part of the study examines the results of combustion of the (LP gas) as a combustible blend of hydrocarbon gases have normally definite caloric value of 46MJ/Kg, the LP gas includes by volume for summer time sixty five percent of ButaneC_4H_{10} and thirty five percent of Propane C_3H_8. These percentages will reverse in the winter time as Propane gives more flammability than Butane.

The investigation will reveal the blowoff conduct in two cases of different confinement shapes at the combustor exit nozzle. The first shape is the cylindrical exit nozzle and the cone shape or conical nozzle. The modes used premixed and partially premixed, in the first mode the air and fuel mixed prior to the combustion zone and help that mixing by swirling the flow through the means of tangential inlets and in the latter adding a fuel injector at the inject fuel at the center of combustion zone to prevent flame from blow out.

The flame initiates the combustion since it is close to nozzle mouth and with more rising air mass flow rate affects the air to fuel ratio and alter this proportion of value to lower value relying on the amount of air reaching to very lean blend and resulting flame disappearance that is clarified as a blowoff phenomenon.

Figure 2denotes the outcomes of experimentations premixed mode blowoff flame conduct of the two confinements both of them are open flame one is cylindrical exit end and the other is conical nozzle shape both of them they using LP gas and the curve represent verses of total mass flow rate with equivalence ratio which is cover lean and rich area. Never the less, the of fuel from the left to right on the curve mean growing of equivalence percentage and goes from lean to rich, according to this the blowoff boundaries developed more than from its value at lean blend. The two curves are close to each other and more improvement for the cone one than the cylindrical as they approach to the unity value of equivalence ratio, but the extended of the blowoff boundaries after $\emptyset = 1$ belongs to the fact the wide area given by conical cup will allowed the central recirculation zone to not breaking down and the mixture still get better shape to continue the flame unlike the other case of cylindrical shape. The development of additional con shape to the burner is essential through the blowoff boundaries enchantment. Therefore, the con shape confinement case needs air more than cylindrical confinement to initiate the blowoff and it denotes the burner with con shape exit will be equivalent in proportion and less than cylindrical cup in which growing air results in maximizing the real air to fuel proportion and as a sequence lessening the $\emptyset$of the fuel in use.

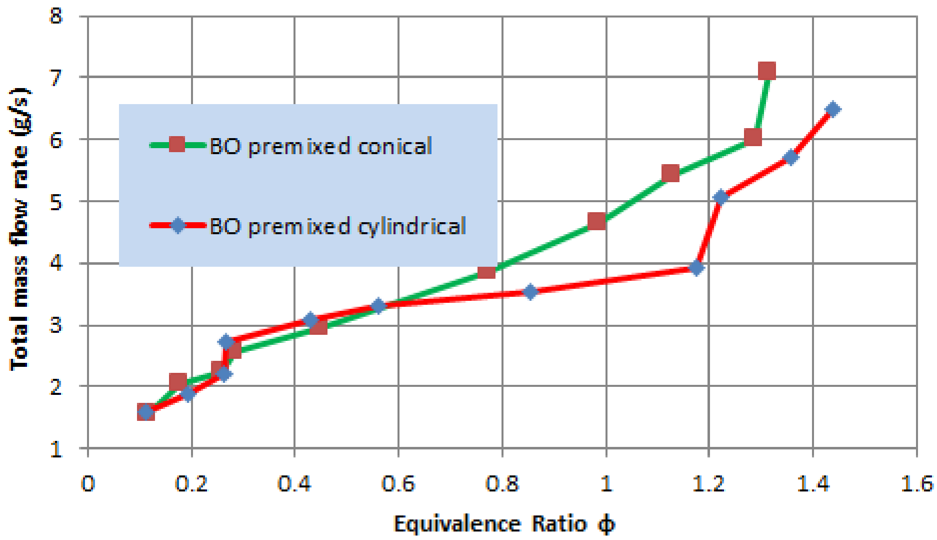


Figure 2: Comparison of the Blowoff Limits Between Conical and Cylindrical for Open Flame for Premixed Mode with Equivalence Ratio.

Figure 3 shows three photos for the conical cup flame. Photo I refers to the form of flame straight after beginning the combustion operation that the CRZ at the beginning of the initiative then, the cleared region near the limitation level of the exit orifice wall has semi spiral form at the central of the combustor exit orifice diameter as seen in image II and with

growing amount of the oxidizer the CRZ begins to be fragile and unsteady as seen in image III, then the flame vanishes and blow outs. The additional conical cups affect straight in the process of losing heat in which the cup directs the flame and hinder its loss. It means to hinder the relocating of the cold gases from the outside to inside the flame therefore hinder reducing the flame or stop the blowoff.

I II III

Figure 3: Flame Shapes for Conical Mouth Open Flame.

Another significant relation represent in figure 4 refers to the total mass flow rate verses with heat input as the latter is related directly with the amount of mass flow in the system and rely as well on the caloric value of the operational fuel LP gas. So, the conduct of blowoff boundaries of the both curves is almost the same linearity shape and the difference between then unimportant.

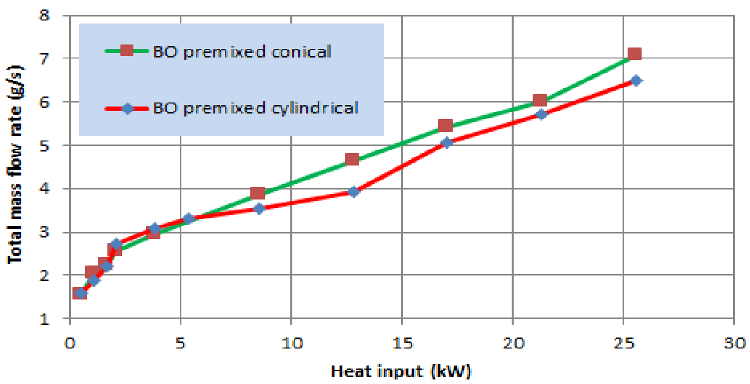


Figure 4: Comparison of the Blowoff Limits Between Conical and Cylindrical for Open Flame for Premixed Mode with Heat Inputs.

Another mode of combustion has been consider in this paper, the partial premixed is examined and indicates that the enhancement average of blowoff boundaries on the case of con shape cup as shown in figure 5. The blowoff boundaries curves of cylindrical confinement and burner with con shape almost the same conduct but with improving the average trend

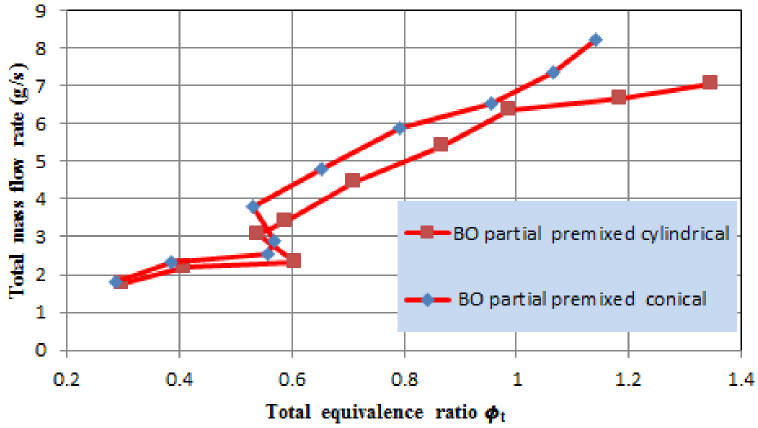


Figure 5: Comparison of the Blowoff Limits Between Conical and Cylindrical for Open Flame for Partial Premixed Mode with Total Equivalence Ratio.

The heat input of the partial premixed doesn't display as shown in figure 6 a valuable variance between open and confined flame in the lean side and give small insignificant between the two curves after stochiometric proportion , this is because of the impact of the additional fuel through the injector nozzle that strengthens the blowoff limit

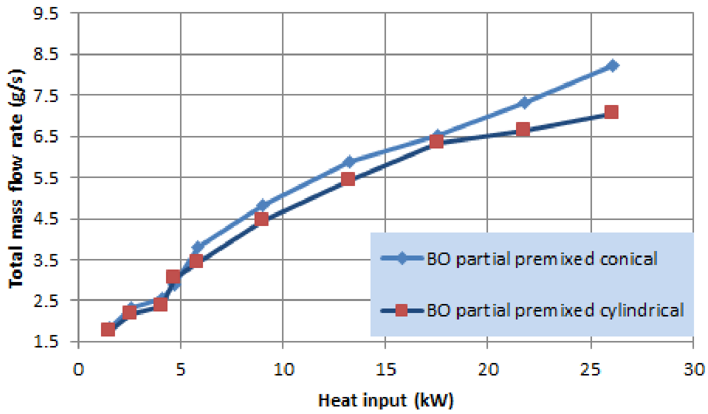


Figure 6: Comparison of the Blowoff Limits Between Conical and Cylindrical for Open Flame for Partial Premixed Mode with Heat Input.

CONCLUSIONS

There is no doubt the impact to integrate confinement with a shape of con to the combustor exit nozzle for premixed combustion way improves the blowoff boundaries for the LP gas minimally in the extent of empirical dimensions as its maintains the temperature confined longer than open flame. Furthermore, the partial premixed combustion method of the same fuel and for both cases decrease the event of the blowoff occurrences, it is because of the impact injected fuel to the combustion zone. Moreover, heat input has almost similar curve trend for both confinement shapes.

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AUTHOR'S PROFILE

Mr. Haidar Janna, currently doing his Master in Power Engineering in Department of Mechanical Engineering at College of Engineering University of Al-Qadisiyah, Al-Qadisiyah, Iraq. He has contributed in publish in a international journal.

Mr. Mohammed Abdulsada, working as Assistant Professor from 2012 itself in Department of Mechanical Engineering at College of Engineering University of Al-Qadisiyah, Al-Qadisiyah, Iraq. He has contributed in publish of more than 11 international and national journals. And participated in more than 13 Conferences and presented his papers. From 2009-2012 he worked as Instructor and Lab Demonstrator at Cardiff University/ School of Engineering /Mechanical Department/ Energy Institute Impact Water Jet Lab and teaching Fluent Tutorial, in the year of 2008-2012 worked as PhD student at Cardiff University/ College of Engineering /Mechanical Department/ Energy Institute. Work in Gas Turbine Research centre in Port Talbot, Wales, United Kingdom, during 2003-2008 worked as Instructor and staff teaching members in college of Engineering at AL-Qadissiyah University, at the time of 1997-2003 worked as Instructor at Higher Institute for General professions and Training preparing in Libya and at the time of 1996-1997 worked as Instructor at AL-Qadissiyah University